“*We are going to need an all-of-government approach to dealing with the gravest cybersecurity threat of this generation - indeed, the greatest threat of this century*”

Arthur Herman, Senior Fellow, Hudson Institute, LINK

The recent announcement of Australia’s $1 billion investment in PsiQuantum has reignited focus on quantum technologies.

This bold commitment demonstrates a strong vote of confidence in the transformative potential of quantum technology, with quantum computing being just one of its many facets.

However, it also prompts critical questions about the maturity of the technology and the prudence of such a substantial investment. In this discussion, we will demystify quantum technology, assess its feasibility, and provide insights into the challenges and realities of commercialisation.

By investing heavily in a single company, the government has taken a considerable risk, particularly given the significant uncertainties surrounding quantum technology - most notably quantum computing. If the government remains in office long enough, this decision could prove to be one of lasting regret.

Previous Newsletters, including this one, are available on our site in pdf HERE

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Quantum Technologies: Separating Hype from Reality

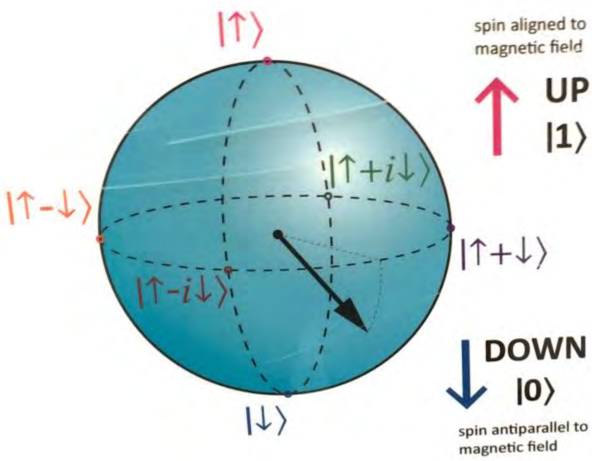
Quantum Fundamentals: What We Know and Don't Know

At its core, quantum technology harnesses quantum mechanical phenomena such as superposition (the ability of particles to exist in multiple states simultaneously) and entanglement (the instantaneous link between particles over great distances). While these principles are well-established in physics, translating them into practical technologies has proven exceptionally challenging. Current quantum systems remain highly unstable and prone to errors.

Key challenges include decoherence, error rates and scalability which we discuss below.

Quantum Technology: Three primary areas

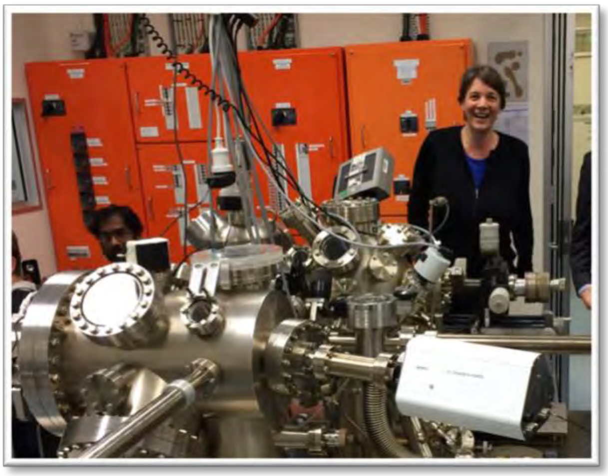
1. **Quantum Computing:** leverages the principles of quantum mechanics to perform computations that are exponentially faster than classical computers. This technology utilises quantum bits or qubits, which can exist in multiple states simultaneously, enabling them to process information in parallel.



The Bloch (!) sphere represents the many possible superposition states of a spin qubit such as a single electron bound to a P atom

Key areas where quantum computing is expected to be most useful include:

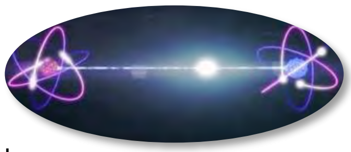
- *Material Science*: By simulating molecule behaviour, accelerate new material discovery
- *Drug Discovery*: By simulating molecular interactions, accelerate new drug discovery
- *Artificial Intelligence*: Enabling faster and more accurate prediction and inference.
- *Optimisation*: Solve complex optimisation problems, such as logistics, modelling
- *Cryptography*: quantum-resistant cryptography, ensuring more secure communication



Professor Michelle Simmons, Founder and CEO of Silicon Quantum Computing behind an early quantum computer, UNSW 2016

Progress in quantum computing has been steady but slower than many predicted. While companies like IBM and Google have achieved important milestones, we're still far from quantum computers that can solve practical problems better than classical computers.

2. **Quantum Communication**: leverages the principles of quantum mechanics to secure and enhance communication protocols. It offers unparalleled security by exploiting the properties of quantum particles, such as photons. Key applications of quantum communication include:



- *Quantum Key Distribution (QKD):* enables the secure distribution of cryptographic keys between two parties, ensuring the confidentiality of communication.
- *Quantum Teleportation*: involves transferring quantum states between distant locations
- *Quantum Random Number Generation:* used to generate truly random numbers for cryptographic purposes, enhancing the security of communication systems
- *Quantum Link Verification (QLV*): involves using quantum mechanics to ensure the physical security of fibre optic cables.

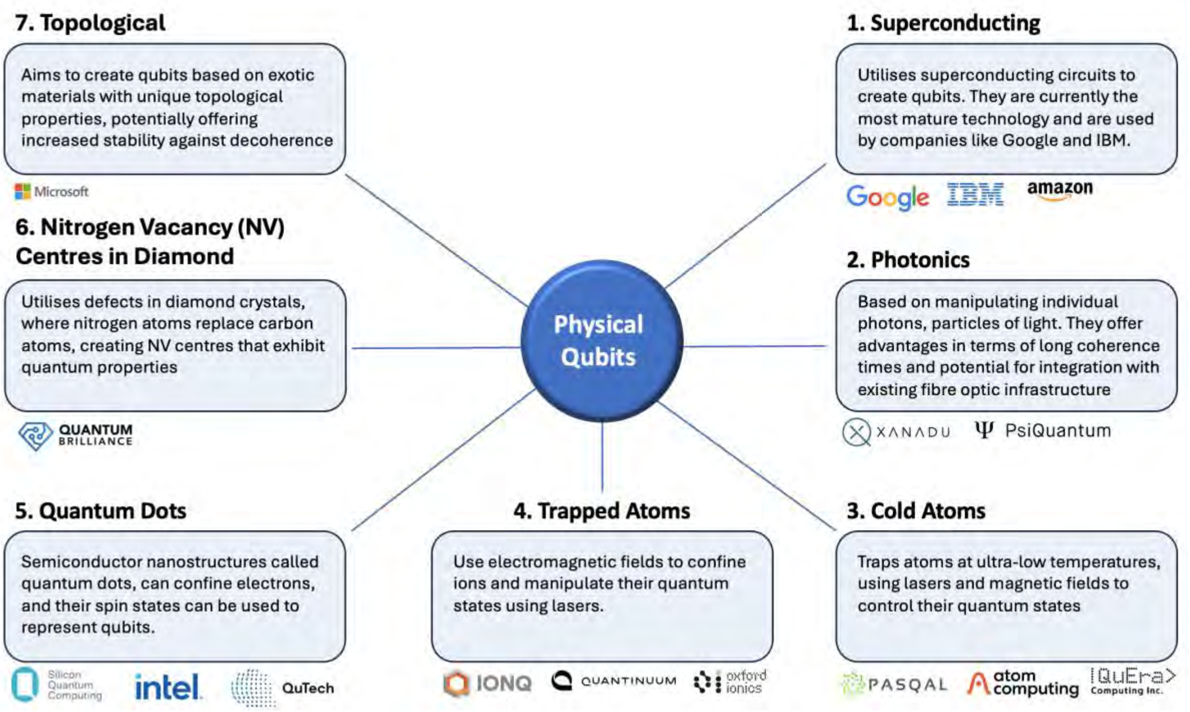
3. **Quantum Sensing** is being used in various applications, though it's still in its early stages of commercialisation. These applications include:

- *Navigation*: Quantum gyroscopes, quantum magnetometers
- *Medical Imaging*: Quantum MRI
- *Mineral Exploration*: Quantum gravity sensors
- *Environmental Monitoring*: Quantum sensors
- *Defence and Security*: Quantum radar, Quantum sensors

Physical versus Logical Qubits

Physical qubits are the fundamental units of information in quantum computers. Unlike classical bits, which can represent either a 0 or a 1, physical qubits exploit the principles of quantum mechanics, specifically superposition and entanglement, to exist in a combination of both states simultaneously.

As of 2024, researchers are exploring seven different approaches to build physical qubits shown below LINK :



Currently there are seven different approaches to building physical qubits

Each of these approaches has its advantages and disadvantages, and there is no clear consensus on the best path towards building a practical, large-scale quantum computer. Companies and research groups are actively pursuing different technologies, believing that their approach will ultimately lead to scalability and commercial viability.

Challenges in Developing Physical Qubits

Physical qubits are inherently unstable and fragile, susceptible to environmental noise and errors. Overcoming these challenges is crucial for building reliable and scalable quantum computers.

Various sources highlight several key issues:

- **Decoherence**: Interactions with the environment, such as heat or electromagnetic radiation, can cause qubits to lose their quantum coherence, leading to errors in computations.
- **Error Correction**: Qubits are prone to errors due to decoherence, crosstalk (interactions between adjacent qubits), and imperfections in the materials used to create them. To mitigate these errors, researchers employ quantum error correction techniques, encoding quantum information into multiple physical qubits to form more robust logical qubits.

- **Scalability**: Building quantum computers with a large number of qubits while maintaining stability and low error rates is a significant challenge. Entanglement becomes increasingly difficult to manage as the number of qubits grows. Current quantum computers have around 1,000 physical qubits, far from the millions potentially needed for complex applications like breaking RSA encryption.

- **Materials Engineering**: The performance of physical qubits heavily depends on the quality and uniformity of the materials used in their fabrication. For example, defects in materials can lead to decoherence, and variations in qubit properties can introduce errors. Advancements in materials science are crucial for creating high-fidelity qubits with low error rates.

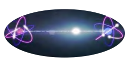
Logical Qubits: While companies often emphasise the number of physical qubits they have achieved, this metric alone does not reflect the true progress towards a functional quantum computer. What matters is the number of logical qubits, which are formed by combining multiple physical qubits and implementing error correction.

Logical qubits are fault-tolerant, stable units of quantum information built from multiple error-prone physical qubits. They are essential for reliable quantum computation because physical qubits are inherently unstable and susceptible to errors. Quantum error correction codes combine hundreds of physical qubits to create a single logical qubit that is resilient to errors. The number of physical qubits needed per logical qubit depends on the physical qubit error rate and the chosen error correction code.

As the error rate decreases, the number of physical qubits needed per logical qubit decreases, making it easier to scale up the system.

The Quantum Landscape: A Critical Assessment

The following table provides a high-level status of the three major forms of quantum technologies, outlining their major challenges and when we can expect practical use.

Quantum Area	Current Status	Major Challenges	Timeline to Practical Use
Computing 	Noisy Intermediate-Scale Quantum (NISQ) devices with 100-1000 qubits	Error correction, qubit stability, scaling	5-10 years for specialised applications; 10-20+ years for general-purpose systems
Communications 	Limited demonstrations of quantum key distribution	Cost, scalability, technology maturity, error correction	5-10 years away from practical deployment
Sensing 	Most mature quantum technology	Stability, scalability, manufacturing, data processing and interpretation	Likely to see practical applications first

Global interest – Global threat

Quantum technology has potentially important national security and other economic implications. Besides offering profound computational advantages, countries that master quantum technology could tap satellite-free navigation, for example, and use new quantum-based cryptographic techniques to protect secrets. On the more ominous side, nation states may be able to hack secrets protected by current methods.

"A single quantum attack on one of the five largest financial institutions in the U.S. disrupting access to the Fedwire Funds Service payment system would cause a cascading financial failure costing anywhere from $730 billion to $1.95 trillion."

Arthur Herman, Senior fellow at the Hudson Institute and director of the Quantum Alliance Initiative LINK

Global Quantum Leadership: Key Players and Their Progress

The following table provides a summary of the top 5 global players:

Company	Technology	Current Status	Key Products /Achievements	Primary Challenges	Notable Aspects
IBM	Super-conducting qubits	433-qubit processor (Osprey)	Cloud access to quantum computers	• Error rates • Coherence time	Strong roadmap but frequent timeline revisions
Google (Alphabet)	Super-conducting qubits	72-qubit processor (Bristlecone)	Quantum supremacy claim (2019)	Scaling beyond proof-of-concept	Focus on error correction and quantum advantage
Psi-Quantum	Silicon photonic qubits	Building first utility-scale computer	Major backing including Australian govt ($1B)	Yet to demonstrate working system at scale	Claims more scalable approach than competitors
IonQ	Trapped ion qubits	32 algorithmic qubits	Cloud access through major providers	• Scaling speed • Processing capacity	Higher fidelity qubits compared to other approaches
Xanadu	Photonic quantum computing	Cloud-accessible photonic chips	• Quantum networking • Communic-ations solutions	Achieving practical quantum advantage	Lead in photonic quantum software development

Australia's Position in the Quantum Landscape

Australia's position in quantum is based on a strong academic foundation in universities such as UNSW, UQ and UTS.

Eighteen months ago, the Australian government launched the National Quantum Strategy. This investment has been backed in by private capital, with over $179 million invested in Australian quantum companies over the same time. LINK

Australia's national quantum industry is now home to 38 domestic and international firms, and 26 Australian research organisations, which are producing world leading quantum sensing, communication and computing.

By far the most significant announcement by the government was the $1 billion PsiQuantum deal. However, with a changing government in Queensland and many more hard questions being asked, it will be interesting to see where this goes.

Key Australian Players

Company	Focus	Status	Notable Aspects
Silicon Quantum Computing	Silicon-based quantum computing	Early development stage	Led by Michelle Simmons' pioneering work
Q-CTRL	Quantum control software	Revenue generating	• International customer base • Strength in error correction and system optimisation

Strategic Position: Australia ranks among the top 5 nations globally in quantum research. It is strong in quantum software and error correction and has a growing quantum engineering capability. Australia's challenge is that it has a limited large-scale manufacturing capacity and companies will need to go off-shore to produce hardware.

Investment and Market Reality Check

The quantum technology market has attracted significant investment, with governments and private sectors committing billions as illustrated in the following table LINK:

Country	Quantum investment (US$)	%GDP
China	$15 billion	0.088%
Israel	$405 million	0.082%
The Netherlands	$684 million	0.067%
Germany	$2.7 billion	0.064%
Canada	$949 million	0.047%
France	$1.8 billion	0.04%
UK	$1.2 billion	0.038%
India	$808 million	0.025%
US	$3 billion	0.012%
Australia	$1 billion	0.012%

Top 10 Country Investments in Quantum. Australia is tenth by percent of GDP

However, this enthusiasm should be tempered with realism:

- Many quantum startups have yet to demonstrate viable products
- Technical roadmaps often prove optimistic
- Competition from improved classical computing continues to advance

The PsiQuantum investment represents a long-term strategic bet rather than an investment in immediate returns. Similar investments in other countries have seen timelines repeatedly extended.

Conclusion

Despite the optimism, experts estimate that widespread commercialisation of quantum technologies, in particular quantum computing, is still several years away. Some sceptics argue that building practical, large-scale quantum computers might be impossible due to the inherent instability of qubits.

Quantum technology is transformative and has the potential to reshape numerous industries. While significant challenges remain, ongoing research, development, and investment are paving the way for a future where quantum computers could revolutionise scientific discovery, technological innovation, and problem-solving across diverse domains.

Now that you're better informed, do you believe the $1 billion investment in a single quantum computing development company was a wise decision?

Stay connected.

Kevin